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# Harvest Sprays for the Control of Fruit Drop

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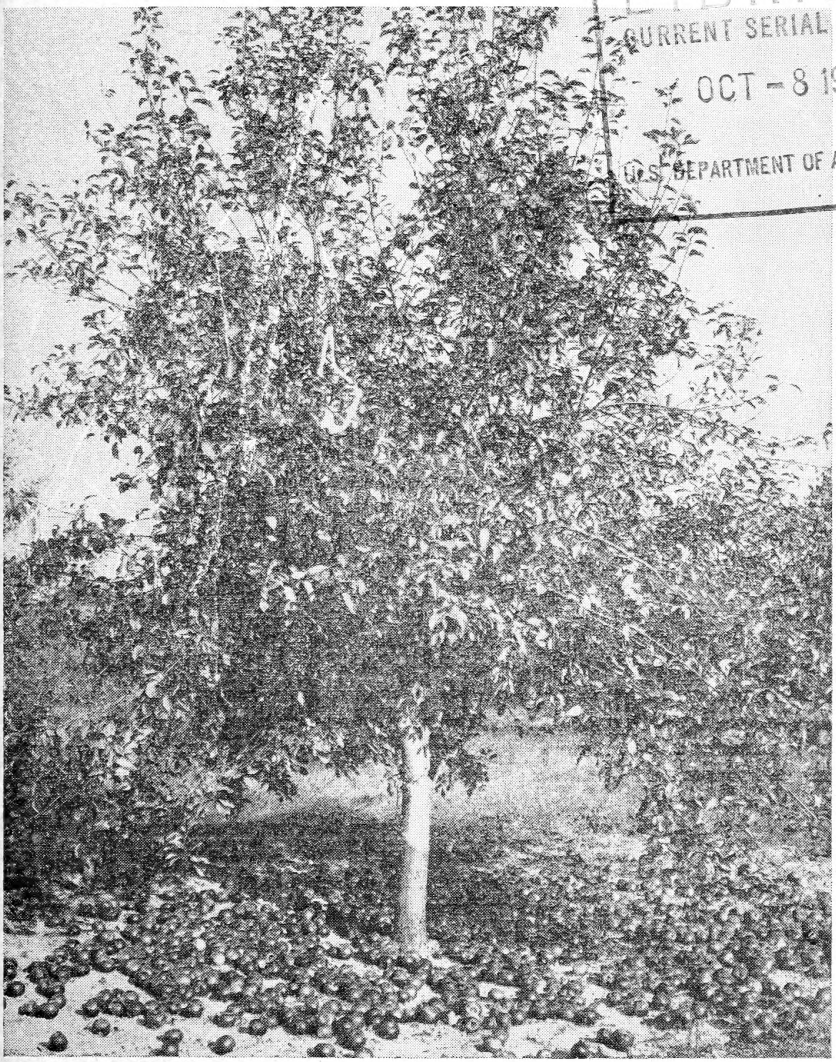

Heavy harvest drop from an 11-year-old Rome Beauty apple tree.

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## SUMMARY AND CONCLUSIONS


Numerous investigators and fruit growers have obtained profitable results by spraying orchard trees at harvesttime in order to control fruit drop—a control measure first used commercially in 1940. This practice now promises to bring considerable savings to many fruit growers and the Nation; it is therefore important that the experience of those who have studied and practiced the use of harvest sprays should be generally known, both by growers and by horticultural investigators. The results of various investigations seem at present to warrant the following conclusions:

Properly used harvest sprays are very successful with many varieties of apples. α-Naphthaleneacetic acid, α-naphthaleneacetamide, and the sodium salt of α-naphthaleneacetic acid are equally effective in retarding fruit drop.

Half-strength sprays (5 p. p. m.) are adequate for most summer varieties of apples, and when applied under favorable conditions have given effective control of dropping with many fall varieties. Full-strength sprays (10 p. p. m.) have proved desirable and may be necessary for fall varieties under many conditions, but generally the small added benefit would not seem to be sufficient to justify the increased expense.

Time of application is the most important single factor in the success of harvest sprays, but thorough coverage to reach the fruit stems is also essential. Generally 1 to 3 days are required for these sprays to become effective. Intensity of effect usually reaches a peak in 5 or 6 days and may remain at a high level for 10 days to 3 weeks, varying with such factors as variety, tree condition, and temperature; after this period the effect is rather quickly dissipated. Consequently, as a general rule, the sprays are most effective when applied at the very beginning of the harvest drop. If these sprays are applied too far in advance of drop or are delayed until drop is well under way, little or no effect may be realized.

If harvest sprays are properly timed and thoroughly applied a single application will usually give all the protection it is possible to achieve. A second application 4 to 6 days later, however, is recommended for some varieties and under conditions where exact timing is

difficult or problematical. By making two applications (the first a few days ahead of the expected drop), the chances of hitting the fruit at the most receptive period are of course greatly increased.

The addition of small quantities of summer oil (1 pint to 1 quart per 100 gallons) has generally resulted in slightly increased effectiveness of harvest sprays.

Harvest sprays are more effective when applied at relatively high temperatures (80° to 85° F.) than when applied under cooler conditions (55° to 60°). A somewhat higher spray concentration might be used on some varieties on days or parts of days when the temperature is relatively low.

No direct effect of harvest sprays on fruit maturity has been reported. Fruit receiving harvest sprays, however, should not be allowed to remain on the tree too long after the normal harvest period, since it may become overmature.

Promising results with harvest-spray substances applied in dust form to McIntosh apples have been obtained. The chief advantage of dusting would seem to be the rapidity and uniformity with which applications could be made.

Results with harvest sprays on pears, particularly the Bartlett and Bosc varieties, have been generally satisfactory. The time of application, spray concentration, and duration of effect are essentially the same as for most varieties of apples.

Harvest drop of stone fruits is not generally a serious problem. With apricots the use of harvest sprays has reduced the subsequent fruit drop, whereas with peaches no appreciable effect has been obtained.

## HARVEST DROP A SERIOUS PROBLEM

Losses as a result of preharvest and harvest drop have long been a serious problem of apple and pear growers. As the fruits approach picking maturity they tend to loosen from the spur and considerable quantities may drop prior to and during the picking operation. Such fruit is badly bruised and if salvaged at all has a low value compared with that picked from the tree. This tendency for fruits of many varieties to loosen and drop as they approach proper picking maturity has led growers to advance the picking dates in some instances, with reduced color, reduced size, and poorer storage quality as possible results.

Such fruits as Bartlett pears and summer and fall varieties of apples generally are increasing in size and weight at the time they are harvested. Therefore, early or immature harvesting of the crop may appreciably reduce total tonnage.

In 1939 it was shown by Gardner, Marth, and Batjer (*7*) [1] that a group of chemical compounds, generally referred to as growth-regulating substances or hormones, when used as sprays in dilute concentrations, would inhibit abscission and thus effectively retard the preharvest drop of apples. After this discovery, proprietary preparations containing the effective substances were made available to fruit growers. In 1940, the first year of commercial use of harvest sprays,

[1] Italic numbers in parentheses refer to Literature Cited, p. 15.

approximately 30,000 to 35,000 acres of apples were sprayed; in 1941, approximately 50,000 to 55,000 acres of apples were sprayed; and in 1942, 75,000 to 80,000 acres of apples and pears received harvest-spray applications.[2]

With the rapid expansion in the use of harvest sprays for retarding fruit drop, there have been variations in results under various conditions; it seems desirable to bring together in this publication both experimental and observational information that might aid in the more effective use of these sprays.

## EFFECTIVENESS OF VARIOUS CHEMICALS ON APPLES

Of a number of compounds tested on apples at Beltsville, Md., in 1939, α-naphthaleneacetic acid, α-naphthaleneacetamide, and the metallic salts of α-naphthaleneacetic acid were outstanding in effectiveness (*7*). Somewhat less effective were the methyl and ethyl esters of α-naphthaleneacetic acid. The indole compounds (indolebutyric, indoleacetic, and indolepropionic acids) were found to retard fruit drop somewhat, but they were regarded as definitely inferior to the α-naphthaleneacetic acid group. Additional chemicals were tested in 1940 (*2*), and tetralin–6–acetamide was found to be effective when used at relatively high concentrations. Other compounds closely related to α-naphthaleneacetic acid, namely, β-naphthoxyacetic acid, α-naphthalene acetonitrile, α-naphthalene methyl thiocyanate, and α-naphthalene methyl isothiocyanate, proved totally ineffective when tested on the Williams variety of apple.

In the first experiments conducted at Beltsville, where direct comparisons were made between α-naphthaleneacetic acid and α-naphthaleneacetamide, it was found that these materials were so close in their degree of effectiveness that it was difficult to determine that any real difference existed. Subsequent comparisons at Beltsville (*2*) and elsewhere have substantiated this conclusion. Hoffman (*12*, *13*) has made comparative tests on several varieties of apples with both compounds as well as with the sodium salt of α-naphthaleneacetic acid. His results showed no essential difference between the three materials. Greve, Kadow, and Guy (*8*) likewise found no significant difference in the effectiveness of these three chemicals under Delaware conditions. Enzie and Schneider (*6*), working with the Stayman Winesap variety in New Mexico, seemed to find α-naphthaleneacetic acid slightly more effective than the acetamide, while Murneek (*17*), working with the same variety, obtained somewhat better results with α-naphthaleneacetamide.

In experiments with harvest sprays trees receiving the same treatment commonly vary greatly in fruit drop. Even with relatively large numbers of trees per treatment it is necessary to obtain differences of considerable magnitude before it can be concluded with any degree of certainty that real differences exist between treatments. Until a more accurate measure of results than counting fruits dropped is evolved it seems reasonable to assume that α-naphthaleneacetic acid, α-napthaleneacetamide, and the sodium salt of α-naphthaleneacetic acid are about equally effective in retarding fruit drop.

[2] Acreage estimates for the various years are based on the sales of harvest-spray materials by the various manufacturing companies.

## SOURCE OF SPRAY MATERIALS

In all the experimental work carried on at Beltsville the pure chemicals were dissolved in small quantities of ethyl or methyl alcohol and added directly to the water in the spray tank. α-Naphthaleneacetic acid, the sodium salt of α-naphthaleneacetic acid, or α-naphthaleneacetamide, as supplied by several reliable chemical companies, can be used as indicated. Since, however, these chemicals are not readily soluble in water and it is not practicable for growers to measure accurately the small amounts necessary, several proprietary commercial preparations [3] have been placed on the market in convenient form for use by orchardists. These preparations consist of weighed amounts of active chemicals mixed with powdered fillers or liquid solvents designed to facilitate quick solution and uniform mixing when they are added to the spray liquid.

## FACTORS INFLUENCING EFFECTIVENESS ON APPLES

### Concentration

So far as known at the present time the directions for use accompanying all the proprietary commercial preparations are calculated to give a spray solution of 10 parts per million (p. p. m.) or 0.001 percent concentration of active ingredient.

Since effective concentration is related to variety, stage of maturity, temperature, and other factors, no inflexible recommendation can be made. Some of the results pertaining to concentration are summarized in table 1. Sprays containing relatively low concentrations of active ingredient have proved very effective on summer varieties of apple, particularly Williams, Early McIntosh (table 1), and Oldenburg (Duchess). Extensive experimental and commercial results indicate that half-strength sprays (5 p. p. m.) on most summer varieties will provide effective control of dropping. With the Williams variety even one-fourth strength (table 1) has given satisfactory results.

TABLE 1.—*Relation of concentration of effectiveness of harvest sprays on apples*

| Variety | Spray concentration | Apples dropped | State and literature reference |
|---|---|---|---|
| | *P.p.m.* | *Percent* | |
| Early McIntosh | 0 | 78.0 | Maryland (*7*). |
| | 2.5 | 13.6 | |
| | 5.0 | 5.4 | |
| Williams | 0 | 13.0 | Maryland (*1*). |
| | 1.25 | 3.5 | |
| | 2.5 | 1.7 | |
| | 5.0 | 1.8 | |
| Wealthy | 0 | 36.8 | Massachusetts (*23*). |
| | 5.0 | 30.8 | |
| | 10.0 | 22.2 | |
| Do | 0 | 29.6 | Do. |
| | 5.0 | 30.9 | |
| | 10.0 | 12.1 | |
| Wealthy | 0 | 21.9 | Massachusetts (*22*). |
| | 10.0 | 12.1 | |
| | 20.0 | 7.7 | |
| | 40.0 | 3.8 | |
| McIntosh | 0 | 21.9 | New York (*7*). |
| | 2.5 | 13.1 | |
| | 5.0 | 13.5 | |
| Do | 0 | 20.2 | New York (*12*). |
| | 5.0 | 3.1 | |
| | 10.0 | 2.9 | |
| Do | 0 | 19.1 | Ohio (*4*). |
| | 2.5 | 8.9 | |
| | 5.0 | 8.1 | |
| | 10.0 | 6.1 | |

[3] Although it is impracticable to provide a complete list of dealers, the following partial list of companies now offering such products is furnished for information only, with the understanding that no discrimination is intended and no guarantee of reliability is implied: California Spray Chemical Corporation, Richmond, Calif.; Dow Chemical Co., Midland, Mich.; Grasselli Chemicals Department, E. I. du Pont de Nemours & Co., Wilmington, Del.; General Chemical Co., New York, N. Y.; Niagara Sprayer and Chemical Co., Middleport, N. Y.; The Sherwin-Williams Co., Bound Brook, N. J.; and Westville Laboratories, New Haven, Conn.

TABLE 1.—*Relation of concentration to effectiveness of harvest sprays on apples*—Continued

| Variety | Spray concentration | Apples dropped | State and literature reference |
|---|---|---|---|
| | *P.p.m.* | *Percent* | |
| McIntosh | 0 | 31.3 | Ohio (*4*). |
| | 2.5 | 17.3 | |
| | 5.0 | 18.3 | |
| | 10.0 | 13.0 | |
| Do | 0 | 15.7 | Massachusetts (*23*). |
| | 5.0 | 14.0 | |
| | 10.0 | 12.3 | |
| Do | 0 | 19.3 | Do. |
| | 5.0 | 6.6 | |
| | 10.0 | 4.2 | |
| Do | 0 | 28.4 | Massachusetts (*21*). |
| | 5.0 | 9.5 | |
| | 10.0 | 6.5 | |
| Do | 0 | 25.7 | Massachusetts (*22*). |
| | 10.0 | 9.9 | |
| | 20.0 | 7.4 | |
| Delicious | 0 | 17.0 | Maryland (*2*). |
| | 2.5 | 7.4 | |
| | 5.0 | 5.6 | |
| | 10.0 | 4.4 | |
| Delicious | 0 | 16.0 | Maryland (*1*). |
| | 2.5 | 7.0 | |
| | 5.0 | 5.0 | |
| Do | 0 | 13.0 | Massachusetts (*22*). |
| | 3.0 | 10.0 | |
| | 6.0 | 8.7 | |
| | 10.0 | 6.6 | |
| Stayman Winesap | 0 | 39.0 | Maryland (*2*). |
| | 5.0 | 16.1 | |
| | 10.0 | 14.9 | |
| Do | 0 | 39.0 | Do. |
| | 5.0 | 11.8 | |
| | 10.0 | 6.5 | |
| Winesap | 0 | 11.0 | Do. |
| | 2.5 | 4.0 | |
| | 5.0 | 3.0 | |
| Do | 0 | 17.2 | Massachusetts (*22*). |
| | 3.0 | 9.3 | |
| | 6.0 | 9.4 | |
| | 10.0 | 2.2 | |

It may be seen in table 1 that while concentrations as low as one-fourth strength (2.5 p. p. m.) resulted in an appreciable reduction in drop of later varieties of apple, increasing the concentration generally gave more effective control. The results of various experimenters, working with a number of varieties, substantiate the earlier conclusion (*7*) that as the concentration is increased the benefit derived from this increase becomes less. In some instances little or no benefit has resulted from increasing the concentration from 5 to 10 p. p. m., while in other cases the stronger spray resulted in appreciably greater effectiveness. Southwick (*22*) found double-strength sprays (20 p. p. m.) somewhat more effective than full-strength (10 p. p. m.) with McIntosh and Wealthy. Still further retardation in dropping of Wealthy was obtained by this investigator when a quadruple-strength spray (40 p. p. m.) was applied. It may be seen from table 1, however, that under many conditions a half-strength spray (5 p. p. m.), if correctly timed and thoroughly applied, will often give effective control of dropping. Increasing the spray concentration above 10 p. p. m. may prove desirable under some conditions, but generally the small added benefit would not seem to be sufficient to justify the expense.

## TIME OF APPLICATION

During the last 3 years of experimentation it has become increasingly evident that timing is the most important single factor in the success of harvest sprays. Early experiments (*7*) were directed toward finding the most effective time of application. In 1939, from experiments involving a number of varieties, it was found that the effect of harvest sprays on most varieties usually reaches a peak in 5 or 6 days after application and may continue very effective for 10 days to 3 weeks, varying somewhat with such factors as tree condition and temperature and considerably with the variety; after this period the effect is rather quickly dissipated. Consequently, as a general rule, it is best to apply the sprays at the very beginning of drop in order to utilize their period of greatest effectiveness. If the spray

is applied too far in advance of the harvest drop the effect will be largely or entirely dissipated before drop begins. An experiment performed with the McIntosh variety in 1939 (*7*) will serve to illustrate this point. In the course of this experiment it developed that spray applications had little or no effect in retarding the main harvest drop, which began 9 to 10 days after the spray was applied. When, however, spray applications were made in this same orchard at the beginning of the main drop, effective retardation in drop was obtained for a period of 8 days, after which a rather abrupt decrease in effectiveness became evident.

Because of the longer effective period and somewhat greater intensity of effect of harvest sprays on summer and some fall varieties, timing of harvest sprays is not as exacting as with such a variety as McIntosh. With Williams, Oldenburg (Duchess), and Early McIntosh the sprays may be applied several days before dropping is expected to start, as judged by the maturity and condition of the fruit. If sprays are applied on these varieties as early as 15 days prior to the expected termination of harvest, good control should be obtained.

With most fall varieties satisfactory results should be obtained if sprays are applied a week or 10 days before the estimated date of earliest picking maturity. In the case of McIntosh, with a relatively short period during which the spray is effective, it is often found desirable to apply the harvest spray when sound, mature apples are beginning to drop. This requires close day-to-day observation on several typical trees scattered throughout the orchard. When fruits that drop just prior to the harvest period are defective in one way or another, the dropping of these fruits may not be a reliable indication that the harvest drop is under way. On the other hand, if spray application is delayed until the dropping of sound, mature fruit has become conspicuous, the treatment may be too late to retard the processes that result in fruit drop.

In order to ascertain if it is possible to stop fruit drop once it is well under way, Batjer and Marth (*2*) applied a spray of 5 p. p. m. concentration to McIntosh trees at Beltsville after the accumulated fruit drop had reached 15 to 30 percent. The results of this test showed clearly that the spray was not effective, since fruit drop continued at about the same rate as if no spray had been applied. Southwick and Shaw (*23*) in one experiment with McIntosh reported continued heavy drop after applying half-strength and full-strength sprays to trees that had an accumulated drop of 10 to 15 percent prior to the time the spray was applied. In another instance with this variety, these investigators (*23*) obtained an apparently significant effect from a harvest spray applied after a 20-percent drop had occurred. Ellenwood and Howlett (*5*), however, failed to obtain any effect from a spray applied to Stayman Winesap once a heavy drop had begun, yet they reported good control when the spray application preceded the drop by a few days. Murphy (*18*), working with McIntosh in Rhode Island, obtained more effective results when the spray was applied September 9 than with a later application on September 13. Unsprayed trees in this experiment had dropped 30 percent of their fruit by September 21.

Thus it seems apparent from the evidence at hand that the effectiveness of harvest sprays becomes progressively less pronounced as fruit

drop and general maturity of the fruit increase. Not all fruits of a given variety growing under the same conditions reach the full-maturity stage at the same time, and under such condition late sprays would probably be effective in retarding drop of the least-mature fruits. In view of the experimental evidence, however, it would seem reasonable to assume that, if the changes resulting in fruit abscission have advanced beyond certain limits, harvest sprays are ineffective in retarding the process and little or no control of dropping is obtained if a majority of the fruits have reached this stage.

## Number of Applications

Early results with harvest sprays (*7*) suggested the possibility that if additional retardation of drop is desired a second application could be made 4 to 7 days after the first application. In an experiment with McIntosh designed to give information on this subject (*2*), it was found that a second application 3 or 7 days after the first spray extended the effective period only 1 to 1½ days beyond that resulting from the single application. With all treatments heavy drop set in 12 days after the original spray was applied.

The results of subsequent experiments along this line by various investigators are summarized in table 2. It will be seen from these data that in only a few instances was there any appreciable benefit from a second application. The slight increase in effectiveness of the two applications in certain cases may have been due to a more thorough spray coverage. The results presented in table 2 suggest that a single application, properly timed with the beginning of the drop, provides all the protection possible to achieve. Perhaps the strong tendency toward abscission as a result of advanced fruit maturity explains the failure of second sprayings to extend the protective period. In a few cases (table 2) where significant benefit was derived from two applications as compared with a single spraying, it is probable that the first application was made somewhat ahead of the drop period.

Table 2.—*Comparison of effectiveness of 1 and 2 applications of harvest sprays to apples of various varieties*

| Variety and picking date | Spray concentration | Spraying date | Apples dropped | State and literature reference |
|---|---|---|---|---|
| | *P. p. m.* | | *Percent* | |
| Jonathan: | | | | |
| October 21 | 0 | | 19.4 | Ohio (*4*). |
| | 10 | Sept. 27; Oct. 4 | 8.4 | |
| | | Sept. 27 | 9.4 | |
| | | Oct. 4 | 8.3 | |
| Stayman Winesap: | | | | |
| October 30 | 0 | | 38.1 | Do. |
| | 10 | Oct. 11; Oct. 16 | 20.4 | |
| | | Oct. 11 | 39.5 | |
| | | Oct. 16 | 22.3 | |
| McIntosh: | | | | |
| September 4 | 0 | | 49.6 | Washington (*19*). |
| | 10 | Aug. 16; Aug. 28 | 17.7 | |
| | | Aug. 16 | 15.8 | |
| September 10 | 0 | | 22.9 | New York (*14*). |
| | 10 | Sept. 1; Sept. 5 | 5.3 | |
| | | Sept. 1 | 7.8 | |
| September 11 | 0 | | 29.9 | New York (*15*). |
| | 10 | Aug. 31 | 12.6 | |
| | 5 | Aug. 31; Sept. 5 | 5.3 | |
| September 25 | 0 | | 10.7 | Do. |
| | 10 | Sept. 15; Sept. 18 | 4.7 | |
| | | Sept. 15 | 2.9 | |

TABLE 2.—*Comparison of effectiveness of 1 and 2 applications of harvest sprays to apples of various varieties*—Continued

| Variety and picking date | Spray concentration | Spraying date | Apples dropped | State and literature reference |
|---|---|---|---|---|
| McIntosh—Continued. | *P. p. m.* | | *Percent* | |
| September 25 | 0 | | 20.2 | |
| | 5 | Sept. 16; Sept. 21 | 2.7 | New York (*12*). |
| | | Sept. 16 | 3.1 | |
| October 1 | 0 | | 43.5 | |
| | 10 | Sept. 18; Sept. 26 | 5.4 | New York (*13*). |
| | | Sept. 18 | 9.1 | |
| September 19 | 0 | | 25.7 | |
| | 10 | Sept. 8; Sept. 12 | 4.8 | Massachusetts (*22*). |
| | | Sept. 8 | 9.9 | |
| September 24 | 0 | | 15.2 | |
| | 10 | Sept. 12; Sept. 17 | 7.2 | Massachusetts (*23*). |
| | | Sept. 12 | 6.9 | |
| Do | 0 | | 19.9 | |
| | 5 | Sept. 12; Sept. 17 | 6.2 | Do. |
| | | Sept. 12 | 6.6 | |
| Unknown date | | [1] | 3.1 | Do. |
| | 10 | [2] | 4.4 | |
| September 21 | 0 | | 24.8 | |
| | 5 | Sept. 9; Sept. 13 | 4.5 | Rhode Island (*18*). |
| | | Sept. 9 | 5.6 | |

[1] 2 applications. [2] 1 application.

Ellenwood and Howlett (*5*) Hoffman (*12*), Southwick and Shaw (*23*), Batjer and Marth (*2*), and Overholser, Overley, and Allmendinger (*19*) have all concluded that if a single application is properly timed with the beginning of drop, little benefit can be derived from additional spraying. However, this unanimity of opinion regarding single versus two applications is based on the assumption that the spraying can and will be properly and accurately timed. In certain years and under some conditions, even with very close observation, it is difficult to know just the most effective time to spray such fall varieties as McIntosh, Stayman Winesap, and others. If the spray is delayed until the dropping is well under way, it may be too late and little or no effect will be obtained. In order to take advantage of the full protective period, which is only 10 to 12 days with some varieties, the spray must be applied just at the beginning of the harvest drop. From a practical standpoint such a procedure may be difficult to carry out. Therefore, one alternative would be to spray somewhat ahead of the drop. If it developed later that this application was made too far ahead of drop and it seemed advisable to delay harvest beyond the protective period of this spraying, a second application could be made 6 to 7 days after the first. By making two applications rather than one, the chances of hitting the fruit at the most receptive period are, of course, greatly increased. As such a plan would actually work out under orchard conditions, it might not be necessary to make two applications on the entire variety or block. If the first spraying is timed somewhat near the harvest period for the variety, picking may be well under way by the time the second application should be made, and consequently only that part of the block still unpicked will need the extra spraying.

The practice of using two applications would seem to merit consideration only with varieties having a rather extended period of harvest drop. Two applications would also prove advantageous on some of the fall varieties under conditions where proper timing of a single application is problematical. There would seem to be no

necessity for using two applications on most summer varieties. Because of the relatively long effective period of the sprays on such varieties, timing the application is accordingly less difficult.

Cost would doubtless be one of the factors in determining the feasibility of making two harvest spray applications. As pointed out previously (p. 5), no inflexible recommendation can be made regarding spray concentration, yet it may be seen in table 2 that very effective control of fruit drop was obtained in all cases where two half-strength (5 p. p. m.) applications were used. Obviously the cost of spray material would be the same as for a single full-strength spray application.

## Thoroughness of Coverage

Harvest sprays to prevent abscission of fruit should for best results be applied to the fruit stem at or near the point of abscission. When applied to the fruit stem and cluster base of Delicious apples (7), these materials were far more effective in retarding fruit drop than when applied to the calyx end only. The lack of transmission of effect to fruit only short distances away from sprayed leaves suggests that leaf coverage is not particularly important. It is certain that sprays applied to entire large limbs have no observable influence on the fruit of adjacent limbs.

In applying harvest sprays, every effort should be made to do a thorough job, particularly in the top of the tree, since the best fruit is usually borne in this part of the tree. Also, when an apple falls from the top it is likely to knock off other fruits on the way down. A tree should be sprayed from both the inside and the outside. It is difficult, if not impossible, to cover adequately a heavily loaded tree from the outside only. The fact that the spray solution is dripping from the foliage is no proof of thorough coverage; each fruit stem must be hit.

Adequate coverage is not as difficult to obtain with long-stemmed varieties, such as Williams, Rome Beauty, Delicious, and Golden Delicious, as with short-stemmed varieties. With the long-stemmed varieties it is relatively easy to reach the stems with the spray solution, and the fruit hangs in such a manner that during the process of spraying the stem cavity often becomes filled with the spray; this insures ideal coverage. McIntosh and York Imperial are examples of short-stemmed varieties with the fruit usually clustered in such a way as to make it difficult to reach the stem with the spray. Only a very thorough and systematic job of spraying will be effective on varieties of this type.

It is not possible to make any definite statement about the amount of spray solution required, because of differences in operators and equipment, as well as conditions under which the spray is applied. As a general rule, however, about 1 gallon of spray solution for each bushel of fruit is essential for satisfactory coverage. At Beltsville (2), 12-year-old Delicious trees received a light spray application of 5 gallons of 5 p. p. m. concentration per tree. Another group of trees of the same variety received the same concentration, but a more thorough application, 10 gallons per tree. In general, the light application proved to be just half as effective in retarding drop. These results serve to emphasize that the control of fruit drop can be no more effective than the coverage given.

### Rain After Application

In experiments at Beltsville little or no decrease in effectiveness of harvest sprays has been noted in cases where heavy rains have occurred several hours after spray applications. By simulating rains with heavy sprayings with water after harvest-spray applications, Overholser, Overley, and Allmendinger (*19*) found that the only serious decrease in effectiveness occurred when the water spray was applied soon (2 hours) after the harvest spray. Trees receiving such treatment dropped 13.4 percent of the fruit as contrasted with 25.4 percent drop by trees not receiving a harvest spray and 7.9 percent by trees receiving no water spray after the harvest spray was applied. Rate of fruit drop was not affected by water spray applied 8 and 24 hours after harvest spray.

### Temperature

The comparative ineffectiveness of some harvest-spray applications on apples at Beltsville in 1940 under relatively cool weather conditions suggested that the temperature prevailing during the drying period of the spray might have been an important factor. Tests with Williams, Delicious, and Winesap in 1942 (*1*) clearly indicated that $\alpha$-naphthaleneacetic acid sprays applied in midday at relatively high temperatures (80° to 85° F.) were more effective at certain concentrations than when applied in the early morning of the same day under cooler conditions (55° to 60°). With the Williams variety, on which hormone sprays are extremely effective, these differences were obtained only when the concentration was below 5 p. p. m. However, with both Delicious and Winesap, both 2.5 and 5 p. p. m. sprays were generally more effective when applied under conditions prevailing at the higher temperatures. Whether or not 10 p. p. m. sprays would have behaved similarly on the later varieties is not known.

Overholser, Overley, and Allmendinger (*19*) have reported similar results with the Delicious variety in Washington. Applications during the warm part of the day were more effective in reducing drop than were those made under cooler conditions of early morning or late afternoon of the same day. These results, together with those mentioned previously, suggest an interrelationship between temperature and effectiveness and indicate the value of using higher concentrations on days or parts of days when the temperature is relatively low. If a limited amount of spraying is to be done, it would seem feasible to make applications during the warmer part of the day for greatest effectiveness.

Temperature plays some part also in the time required for the spray to show worth-while effects after application. With high temperatures 24 to 48 hours may be sufficient; but with relatively low temperatures 3 to 4 days may elapse before the effect becomes apparent. It is believed, however, that low temperature after harvest spraying does not seriously affect the net results, since the rate of normal drop is also slowed up under cool conditions.

### Compatibility of Harvest Sprays With Other Spray Materials

The possibility of increasing the effectiveness of harvest sprays by the addition of supplementary materials has been rather widely

tested. Experiments have also been conducted to determine the compatibility of harvest-spray chemicals with a number of materials commonly used in regular spray schedules. In this publication only the more extensively tested materials will be discussed.

Table 3 summarizes the results obtained by a number of investigators relative to the addition of summer oil to growth-regulating sprays. While the results presented in table 3 are inadequate as proof, yet there seems to be a strong suggestion in most cases that the addition of a small quantity of summer oil increases the effectiveness of the spray. The increase may be due to any one of or a combination of three factors: (1) Increasing the solubility of the growth chemicals; (2) aiding penetration by maintaining an oil film of the substance in contact with the absorbing tissues; and (3) increasing the amount of growth substance available for absorption by increasing the deposit per unit area of tissue.

TABLE 3.—*Influence of summer oil on the effectiveness of harvest sprays on apples*

| Variety | Spray concentration | Apples dropped when spray contained the indicated percentage of oil | | | | | Apples dropped from unsprayed trees | State and literature reference |
|---|---|---|---|---|---|---|---|---|
| | | 0 | 0.125 | 0.25 | 0.5 | 1 | | |
| | *P. p. m.* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | *Percent* | |
| Rome Beauty | 5 | 11.4 | | 9.4 | 7.8 | | 55.0 | Maryland (*7*). |
| McIntosh | 5 | 13.5 | | | 10.5 | | 21.9 | Do. |
| | 10 | 2.9 | | 2.8 | | | 20.2 | New York (*13*). |
| | 10 | 14.1 | 10.2 | | | | 24.3 | Massachusetts (*23*). |
| | 10 | 8.2 | | 4.2 | | | 24.3 | New York (*12*). |
| Wealthy | 5 | 8.4 | | 8.6 | | | 28.2 | Do. |
| Winesap | 10 | 3.2 | 2.6 | | | | 15.4 | Washington (*19*). |
| Delicious | 10 | | 4.8 | | | 2.5 | 23.1 | Do. |

The fact that oil is objectionable in any spray just prior to harvest, particularly for fruit growers who follow a spray program that does not necessitate fruit washing, may be sufficient reason for avoiding its use with harvest sprays, despite the apparent increase in effectiveness. Worthy of consideration, however, is the use of as little as 1 pint to 100 gallons (table 3). The oil deposit on fruit receiving this amount can scarcely be detected, and there seems to be no objectionable modification of the quality of red color such as frequently occurs with higher oil concentrations.

Because of the desirability of delaying harvest-spray applications until the beginning of the harvest drop, there are probably few instances in which harvest-spray chemicals could advantageously be added to the late cover sprays. Kadow and Hopperstead (*16*) pointed out, however, that under Delaware conditions fruit growers may sometimes be required to apply a regular spray on midseason varieties so late that the harvest spray could well be combined with it. These investigators found that α-naphthaleneacetic acid was as effective when applied with nicotine sulfate, Genicide, phenothiazine, or derris as when applied alone. However, in five different tests with the Delicious and Williams varieties, spray solutions containing lime were markedly reduced in effectiveness as compared with harvest sprays containing no lime. Overholser, Overley, and Allmendinger (*19*) also have reported reduced effectiveness with sprays containing lime. Available evidence indicates that growth-regulating chemicals enter

the plant cell as nondissociated molecules. The increased dissociation of the α-naphthaleneacetic acid in a more alkaline solution resulting from the addition of lime may possibly be responsible for the reduced effectiveness reported (*16*, *19*). It is well known that harvest sprays are highly effective in many instances when applied to trees carrying a heavy deposit of spray residue containing lime. In such cases, however, this previously applied lime had probably been converted to the carbonate form and would be relatively inert in its effect on subsequent applications of harvest sprays.

### Varietal Response

The duration of effect as well as the degree of effectiveness of harvest sprays varies considerably with the variety. While no inflexible classification of varieties with respect to response is possible, yet it is apparent from both experimental and commercial results that the most outstanding results have been obtained with summer varieties, particularly Williams, Early McIntosh, and Oldenburg (Duchess). Harvest sprays, when properly timed and thoroughly applied, have been generally effective with Delicious, McIntosh, Stayman Winesap, Winesap, and Rome Beauty. It should be pointed out, however, that with these varieties great variation in results of spraying has been obtained, and in a number of instances failure to obtain control of drop has been reported. Results with late-fall varieties, such as Baldwin and York Imperial, have been generally unsatisfactory, although under certain conditions satisfactory results have been obtained (*7*, *14*). The usual better response of summer varieties is probably due in part to the more active growth status of the tree at the time the fruit is maturing. Also the higher temperatures (p. 11) prevailing at the time of and after the spray application may play a contributing part.

Harvest sprays seem to be less effective under conditions when or on varieties in which the drop is spread over a rather extended period. In such instances it becomes more difficult to time properly the spray application. The harvest drop of York Imperial and McIntosh in southerly regions is characteristically of this type.

### Tree Vigor

Hoffman (*11*) and Southwick (*20*) have shown that vigorous McIntosh trees with a relatively high nitrogen content tend to have a heavier preharvest drop than trees growing at a lower nitrogen level. These investigators point out that such practices as heavy nitrogen fertilization, heavy mulching, and late cultivation may tend to increase the preharvest drop of this variety. Whether or not this relation between nitrogen level and harvest drop holds with other varieties is not known.

There seems to be no definite evidence available indicating the relation between tree vigor or nitrogen level and effectiveness of harvest sprays. It is known, however, that good success with these sprays is dependent on a normal, actively functioning foliage system. If sprays are applied late in the season on late-fall varieties after the foliage has begun to turn, little effect may be obtained. Failure in such cases may possibly be due to both the cool temperature and the foliage condition generally prevailing at the later dates.

### Soil Moisture

Under conditions of soil-moisture shortage, fruit drop is usually a serious problem. Limited experimental evidence and general observations indicate that harvest sprays are only moderately effective where such conditions prevail.

## RELATION OF HARVEST SPRAYS TO FRUIT MATURITY

From 3 years of testing of a number of varieties of sprayed apples in storage Haller (*9*) concluded that apples given harvest sprays with α-naphthaleneacetic acid did not show any direct effect of the sprays on the firmness of the fruit, decay, or break-down, in comparison with unsprayed apples picked at the same time. It should be emphasized that with the effective use of harvest sprays a certain amount of fruit that otherwise would drop remains on the tree. Naturally these fruits are among the most mature, and if they are not harvested within a reasonable period their keeping quality may be seriously impaired. With summer varieties of apples the fruit is likely to become overmature if allowed to remain on the tree even a few days beyond the normal harvest period. Harvest sprays so completely control dropping with many summer varieties that the early maturing fruits remain on the tree more or less indefinitely. If these fruits are not harvested within a day or two after they would have normally dropped if not sprayed, overmaturity may develop, particularly under high-temperature conditions. Under certain conditions and with some varieties, particularly Delicious and Stayman Winesap, water core is likely to develop, with subsequent breakdown in storage, if the fruit is allowed to remain on the tree very long after the normal harvest period for the variety. On the other hand, general quality and storage life of the McIntosh variety under some conditions may be improved by allowing the fruit to remain on the tree for several days to a week longer than would be possible without the effective use of harvest sprays. However, if harvest is delayed too long, with most varieties losses from overmaturity may offset any advantage obtained in added color and drop prevention. With many varieties it is likely that the harvest sprays will prove to have their greatest value in protecting the fruit grower from losses from dropping before and during the normal picking operation rather than in appreciably postponing the desirable harvest period.

## APPLICATION OF HARVEST-SPRAY SUBSTANCES BY DUSTING

In 1941 and 1942 Hoffman, Edgerton, and Van Doren (*14*, *15*) obtained equally satisfactory results on Williams and McIntosh apples with α-naphthaleneacetic acid applied in a talc dust as with this material applied in spray form. Equivalent amounts of α-naphthaleneactic acid (equivalent to 10 p. p. m. concentration) per bushel of fruit were used in the two methods of treatment. According to the results of Southwick (*21*) with Oldenburg (Duchess) and Wealthy apples, dusting was not as effective as spraying, while with McIntosh the results from dusting were variable.

Whether or not dusting as a means of applying harvest-spray substances will prove to be generally as effective as spray with all varieties and under varied conditions remains to be determined. The

chief advantage of dusting would seem to be the rapidity and uniformity with which applications could be made.

## EFFECTIVENESS OF HARVEST SPRAYS ON PEARS

Results with harvest sprays on pears, particularly the Bartlett and Bosc varieties, have been generally satisfactory. The use of harvest sprays on the Bartlett variety by Davey and Hesse (*3*) in California resulted in about a 50-percent reduction in fruit drop. These workers point out that commercial results with these sprays have been so generally satisfactory that the use of them on Bartlett pears in California has become an accepted practice. Successful results with the Bartlett variety have also been obtained in Washington and Oregon. In harvest-spray experiments reported by Gerhardt [4] fruit drop of this variety was reduced from 27 to 7 percent.

In general, the time of application, spray concentration, and duration of effect are essentially the same for pears as for most varieties of apples.

There have been occasional reports of harvest sprays advancing the maturity of pear fruits, but this has not been shown experimentally. As was pointed out in the case of apples, the effective use of these sprays will result in overmaturity of the fruit if it is not harvested at the proper time. This overmaturity of the fruit is not a direct effect of the spray, but a result of fruit that would otherwise have fallen staying on the tree.

## EFFECTIVENESS OF HARVEST SPRAYS ON APRICOTS AND PEACHES

Results with harvest sprays on stone fruits have been variable. Hesse and Davey (*10*) obtained a significant reduction in drop of Stewart apricots. The effective period of the spray ranged from 3 weeks in 1940, when applied at a concentration of 10 p. p. m., to as little as 1 week in 1941, when two half-strength applications (5 p. p. m.) were made. In these experiments an interval of 7 to 10 days intervened between the spray application and any noticeable response, a period considerably longer than the 1 to 3 days usual in the case of apples.

Limited tests with harvest sprays on peaches have proved generally unsuccessful. Hesse and Davey (*10*), by using these sprays, obtained a slight reduction in the subsequent drop of Elberta peaches. These investigators conclude, however, that in no case did the sprays give differences great enough to suggest possible commercial use. Experiments with this variety at Beltsville failed to give beneficial results when the sprays were applied a few days prior to the harvest period.

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